VI.—Summary.

A peculiar depressed basin of about 50 acres in area occurs immediately south of Jubilee Park, Daylesford. It is surrounded on all sides by Ordovician slates and shales, which rise to a height of 100 feet above the floor of the basin. The north and west sides are capped by basalt, under which are deep leads about 50 feet higher than the floor. It is open to the Stony Creek, which flows along the west side. Exposed in sluicing channels, are ligneous shales and clays containing diatoms and fresh water sponge spicules. These have been penetrated by a shaft for over 100 feet.

This basin is considered to have originated by the depression of a block of Ordovician, and to have been flooded by a pre-basaltic stream. It was filled by ligneous clays. The stream entering the basin was carrying similar material. In the quiet backwaters, conditions would be favourable for the growth of diatoms and fresh water sponges. The pre-basaltic stream, and perhaps part of the basin, was then filled by basalt. The twin streams, Sailor's Creek and Stony Creek, developed. While cutting through the basalt bar at the north side of the basin, Stony Creek cut out a wide plain in the easily eroded black shales, undermining any basalt that covered them. The basin was subsequently deepened as the stream entrenched itself deeper into bedrock.

The basin lies at the east extremity of a line of fracture and intrusion in late Kainozoic times. At Eganstown this is known as the Corinella dyke. Shafts through this dyke are supposed to have passed through diatomaceous earth. No trace of this is found around the dump heaps, but one consists largely of a volcanic agglomerate with a large proportion of fine greyish matrix. This was possibly mistaken for diatomaceous earth. Two alternative explanations are considered to account for the known facts. The more probable is that a fractured and shattered zone was developed in the Ordovician rocks. Accompanying this was the explosive injection of volcanic material forming a volcanic agglomerate. The proportion of volcanic material to shattered Ordovician varies at different parts. Contemporaneously, or at a slightly later date, came the intrusion of basalt along the same line of fracture as a dyke, culminating in the west in extrusive volcanic action.

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Art. IV.—*An Olivine Anorthoclase Basalt from Daylesford.*

By D. ORR, B.Sc.

[Read 9th June, 1927.]

Contents.

I.—Introduction.

This paper is mainly concerned with the chemical and petrological character of an alkaline basalt that has been recorded from the Daylesford district (1). It is shown to be an olivine anorthoclase basalt. The recent dissection characteristic of the area is also briefly discussed.

The area covered by the anorthoclase basalt is contained in Quarter-Sheets No. 16 NE. and No. 16 SE., of the Geological Survey of Victoria. Notes on these quarter-sheets appear in Progress Reports No. 8 and No. 9 of the survey. The central portion of the area was later surveyed and mapped on the larger scale of 1 inch to 16 chains by H. S. Whitelaw (2). In all these publications of the survey no distinction is made between the olivine anorthoclase basalt and the normal newer basalts of the area. Its special nature was first noticed during a geological excursion from the University. It was described by Professor Skeats (1) as an olivine anorthoclase trachyte.

II.—General Geology.

The rock formations outcropping in the area are in decreasing order of age:—Ordovician, Older Pliocene, Newer Volcanic, Newer Pliocene and Recent. All have been fully described in the publications of the Mines Department already referred to.

The newer volcanic series which forms a large part of the surface rock of the district is part of the northern outskirts of the great basaltic plain of south-west Victoria. The lava is in the form of separate flows, which have filled up pre-basaltic river valleys, sealing up valuable auriferous gravels. These flows originated from numerous volcanic vents, the volcanic hills built up around which form one of the characteristic topographical features of the district. The mode of eruption in this area differs from that of the main plain, which is considered to have originated by the fissure type of eruption.

III.—Physiography.

The area dealt with in this paper lies on the northern slopes of the Main Divide. The Divide crosses the south-east corner of Quarter-Sheet 16 SE. of the Geological Survey. Leonard's Hill, near the southern extremity of the anorthoclase basalt flow, lies about 20 chains north of the Divide.

The area is one of great diversity of surface, being very deeply dissected by numerous streams which ultimately find their way to the Loddon River. The slopes of the valleys and the Ordovician hills are generally densely timbered, while the elevated basaltic plains have been cleared for agricultural purposes. The numerous volcanic flows have been largely instrumental in the development of the present topography. The volcanic hills around the points of eruption rise well above the general level, and form prominent landmarks. The most prominent of these are Mount Franklin, Bald Hill, Fern Hill, Wombat Hill, Wheeler's Hill, and Leonard's Hill. Whereas the basalt formerly occupied the valleys of the pre-basaltic streams, it is now found on the higher ridges and plains. Frequently twin streams have deeply entrenched themselves on either side of a basaltic flow, which now forms a high flat-topped ridge between the two streams. Sailor's Creek and Stony Creek are twin streams that have entrenched themselves on either side of the anorthoclase basalt flow. The head-waters of both these streams occupy only small surface gutters, which suddenly develop into deep gorges by steep falls over the basalt. Sailor's Falls has a vertical drop of about 100 feet, Stony Creek Falls one of about 50 feet.

All the streams of the area occupy recent deeply dissected valleys. The level of the pre-basaltic streams, as denoted by the present level of the deep leads, is generally 50 feet or more above the present stream level. The most recent flow from Mount Franklin is an exception. It was evidently extruded when present stream level was reached, since the Jim Crow Creek, which flows along the eastern edge of the flow, has much of its bed in basalt. If, as is generally considered to be the case, these pre-basaltic streams had reached base level, the area must have been relatively uplifted in post-basaltic times. To form any reliable opinion as to the manner by which these streams had their erosive power increased an intimate knowledge of the country to the north of Daylesford would be required. The time necessary to acquire this information was not available.

A trip was made along the Jim Crow Creek as far as its junction with the Loddon River at Newstead, about 16 miles north of Daylesford. This creek is formed by the junction of Sailor's and Wombat Creeks. As far as Franklinford, six miles north of Daylesford, it occupies a very steep and deeply dissected valley. Past Franklinford to the junction with the Loddon, the character of the valley changes. The stream flows in an open mature valley, rising on the west and east to low rounded Ordovician hills. The floor is occupied by the most recent basalt flow from Mount Franklin. It was first thought that the cause of this recent dissection, most probably faulting, might be located in the neighbourhood where the change in the nature of this valley took place. An excellent panoramic view over this part of the country to the Loddon is obtained from the summit of Mount Franklin. No indication of any fault escarpment could be noticed.

It is most probable that this open character of the valley of Jim Crow Creek past Franklinford is due to the greater ease of weathering of the Ordovician sediments compared with the basalts, which have confined the streams in the Daylesford district to narrower and steeper valleys. The fact that auriferous gravels, of apparently the same age as the deep lead gravels, outcrop above the present stream level towards Newstead indicates that the cause of the dissection is to be sought still further downstream.

IV.—Olivine Anorthoclase Basalt.

(*a*) *Distribution and General Character.*

The source of this basalt is Leonard's Hill, a big volcanic hill about 20 chains east of Leonard's Hill station, six miles south of Daylesford on the Daylesford-Ballarat railway line. The upper part of this hill shows all the characteristics of a point of eruption, consisting of very vesicular, scoriaceous basalt mixed with finer volcanic material. From this hill the lava flowed north, filling an old pre-basaltic river valley and sealing up the river gravels. These have proved auriferous in the northern part of the area, where the Llewellyn lead has been extensively worked.

The basalt is continuous until the Stony Creek Basin is reached, past which, due to the deep dissection of the Stony and Wombat Creeks, it has been isolated as cappings to flat topped hills; namely, Table Hill, Hard Hill, and the Jubilee Park Hill. On the Quarter-Sheet (No. 16 SE.) the basalt is shown as continuous on the west bank of Stony Creek as far as the Ballarat Road, thus differing from Mr. Whitelaw's map, which shows a ridge of Ordovician, of the same level as the basaltic plateau, breaking the continuity immediately north of the outlet from the basin. Examination showed the latter mapping to be correct. The pre-basaltic stream evidently meandered at this locality.

South of Leonard's Hill, but not connected with it, two parallel basaltic flows extend in a south-easterly direction for a distance of about four miles, where they junction at the Werribee River. From here basalt outcrops intermittently on either side of this stream as it is followed southwards On the northern extremity of each of these flows is a volcanic hill. The hill in the northern extremity of the westerly flow has been isolated from the main flow by stream dissection. Except in places on the surface of the basalt flows, where the land has been cleared, the country here is extremely rugged and thickly timbered. Time did not permit of any detailed examination of these flows or of their relation to the anorthoclase basalt flow. Specimens collected from the two hills at the northern end of each flow, and from an outcrop on the Werribee River, about a mile below their junction, were sectioned. The first two (2200, 2201)[1] were very similar, and resembled a fine grained variety found at the base of Leonard's Hill, though they differed in the absence of anorthoclase. The third specimen was a typical olivine basalt, the phenocrysts of olivine being altered to brown iddingsite. It is therefore probable that these flows are distinct from the anorthoclase basalt flow, and were extruded from the hills at their northern extremities. If this is so, the flows would be older than the anorthoclase basalt flow, as all traces of scoria and ash have been removed from these hills by the processes of weathering, and now only basaltic plugs remain standing above the general level of the flow. Leonard's Hill, however, is in a much better state of preservation, and is therefore younger.

On the surface, the anorthoclase basalt has weathered to a rich red soil similar to that derived from the other basalt of the area. Exposed in a rock face at Table Hill Quarry there is a large lenticular patch, surrounded by unweathered basalt, that has been weathered to a whitish clay. The junction between the two types is quite abrupt. It is rather difficult to picture this as due to the concentration of ordinary meteoric weathering processes; more probably it is due to chemical action of enclosed magmatic waters and gases. That there were abundant is suggested by the common occurrence of calcite filling the vesicles in the rock.

Excellent sections showing the junction between basalt and Ordovician bedrock occur at Stony Creek and Sailor's Creek falls. On the under surface, for a thickness of about 6 inches, the basalt is very vesicular in character.

A number of specific gravity determinations were made on specimens collected from different parts of the flow. They varied from 2·881 to 2·791, with an average of 2·838.

(*b*) *Chemical Character.*

The specimen selected for analysis was collected at Sailor's Creek Falls. At this locality there are numerous large blocks of basalt which split fairly readily, allowing access to fresh rock.

1.—The numbers refer to rock sections in the collection of the Geological Department, University of Melbourne.

Microscopical examination of a rock section of the specimen analysed showed it to be a typical specimen.

The analysis shows a silica percentage of 47·71%. This places the rock in the basalt group. Chemically it is distinctly higher in alkalies and lower in lime and magnesia than the normal basaltic type, typified by R. A. Daly's average of 161 basalts. It therefore belongs to the alkaline suite of rocks.

The high percentage of CO_2 would seem to indicate that the sample taken for analysis was not fresh. Microscopical examination, however, showed that this was not the case. None of the minerals, including the felspars, was decomposed to any extent. Some aragonite occurred in the vesicles. This would indicate a primary origin for the carbon dioxide in the magmatic gases.

According to the Quantitative Classification, the rock would be classed as —Class 1, Dosalane; Order 5, Germanare; Rang 3, Andase; Sub-Rang 4, Andose.

(*c*) *Petrological Character.*

Megascopically it is a dark bluish grey rock, in which small phenocrysts of augite, olivine, and shiny felspar may be distinguished. In appearance it is very similar to the anorthoclase basalts of the Macedon district. Large clear phenocrysts of felspar, some over 1 cm. in length, showing a well-developed cleavage and a lenticular outline through reaction with the molten magmatic liquid, are occasionally found. They are most numerous at Sailor's Creek and Stony Creek Falls, where an abundance of broken material is available for examination. Vesicles lined with zeolites and aragonite are fairly numerous.

The vesicular blocks at Leonard's Hill contain, though not plentifully, large phenocrysts of a clear felspar. Similar crystals are found in the scoriaceous material at Mount Franklin, where they have been identified as anorthoclase. Near the foot of Leonard's Hill is found a very dense, fine-grained type of basalt, in which few, if any, phenocrysts can be recognised with a lens. It occurs in boulders which under the hammer break up into concentric shells.

The microscopical character of the rock has been determined by the examination of a large number of rock sections made from specimens gathered from different parts of the flow. There is a marked uniformity in all these sections, with the exception of those of material from the point of eruption.

Microscopically it consists of phenocrysts of idiomorphic plagioclase, showing distinct though rather fine lamellar twinning, allotriomorphic anorthoclase, granular olivine and hypidiomorphic augite and hypersthene. The ground mass is composed mainly of lath-shaped plagioclase, showing a well marked trachytic arrangement of crystals, with grains of olivine, augite and magnetite. A clear felspar sometimes occurs as an interstitial allotriomorphic mineral in the ground mass. Its refractive index, found by the

Becke method, is less than that of the felspar laths. This is probably sanidine or untwinned anorthoclase. Interstitial glass is sometimes present in small amounts. Aragonite is frequently found in the vesicles [2192, 2202, 2208].

The reaction border surrounding the allotriomorphic crystals of anorthoclase and the corroded outline of the crystals show that they were not in equilibrium with the molten liquid. Their distribution is rather irregular, as, though usually present, they do not occur in all the sections. Twinning cannot be distinguished, but they have the characteristic wavy extinction of anorthoclase. The refractive index is lower than that of the plagioclase felspar, whose refractive index, determined by the Becke method, is distinctly higher than, while that of the anorthoclase is practically the same as that of the balsam. The size varies from large phenocrysts [2204, 2205, 2206, 2207] to small corroded remnants [2191, 2193, 2195]. The smaller crystals are crowded with inclusions, but the interior of the large ones, although surrounded by altered reaction border with inclusions, is quite clear and free from inclusions.

The predominant pyroxene is a violet-grey titaniferous variety of augite. Hypersthene occurs in a subordinate amount [2191, 2193, 2203, 2195], being distinguished by its straight extinction and faint pleochroism.

The felspar laths were determined, wherever possible, by the Michel Levy statistical method, and were found to vary from an acid labradorite to a basic andesine.

Generally the rock is fairly fresh. Calcite is developed at the expense of the plagioclase [2191, 2194, 2206], frequently forming central inclusions in the larger phenocrysts. The olivine is generally altered to brown iddingsite [2195, 2199, 2206], and more rarely to serpentine [2192]. Serpentine, not directly associated with olivine, is frequently present [2203, 2208, 2195].

This microscopical examination shows the rock to be an olivine anorthoclase basalt.

Sections of the scoriaceous type from the summit of Leonard's Hill show a few porphyritic crystals of magnetite, olivine, augite and, in one case [2197] hornblende, set in a decomposed glassy ground mass. Two sections were prepared containing the large felspar phenocrysts. In one case [2196] the phenocryst had a well-developed cleavage and a wavy extinction inclined at 3-7° to the cleavage. The refractive index was practically the same as that of the balsam. It is therefore anorthoclase. In the other section [2198] the felspar showed broad lamellar twinning and a higher refractive index characteristic of the plagioclase felspars.

In the dense fine-grained variety found at the foot of Leonard's Hill [2199], the trachytic structure, so characteristic of the felspar laths in the ground mass of the other sections, is absent. The phenocrysts are smaller and less numerous, anorthoclase being represented by one small corroded remnant.

(*d*) *Age.*

The anorthoclase basalt flow covers auriferous drifts of the same age as those preserved beneath the normal basalt flows of the district. Leonard's Hill, compared with other hills, such as Fern Hill, Bald Hill, Wombat Hill, points of eruption of normal basalt types, is of the same order of preservation. The deep lead, like the other deep leads, lies about 50 feet above present stream level, and therefore was formed before the rejuvenation of the streams, causing the present deep dissection, took place. The flow therefore belongs to the newer basaltic period of volcanic action, and is late Kainozoic in age.

The anorthoclase basalts of the Macedon district are considered (3) to have been extruded immediately prior to the normal newer basalts. In this area, however, if the age assigned to the basalt flows immediately south of Leonard's Hill is correct, the extrusion of the normal types had already commenced when the anorthoclase basalt was poured out.

(*e*) *Comparison with Newer Basalts and with other Alkaline Rocks in Victoria.*

An average of six analyses of newer basalt from the Camperdown district is given with the chemical analyses. This may be taken as typical of the newer basalts of Victoria. Compared with R. A. Daly's average, it shows a marked similarity throughout. The normal newer basalts are therefore typical olivine basalts from which the anorthoclase basalt differs both chemically and mineralogically.

CHEMICAL ANALYSES.

	1.	2.	3.	4.	5.
SiO_2	47·71	48·83	51·52	48·78	48·00
Al_2O_3	15·66	16·69	16·58	15·85	14·11
Fe_2O_3	2·47	2·66	2·35	5·37	5·61
FeO	8·43	8·40	7·68	6·34	6·11
MgO	4·45	5·56	4·03	6·03	8·81
CaO	7·53	7·95	6·10	8·91	8·68
Na_2O	3·69	2·92	4·11	3·18	3·01
K_2O	2·23	2·10	2·99	1·63	1·25
H_2O +	1·93	0·66	0·22	1·03	0·73
H_2O −	0·48	1·34	1·39	0·73	0·80
CO_2	2·67	tr.	tr.	—	—
TiO_2	1·96	2·85	2·15	1·39	2·20
P_2O_5	0·89	0·74	0·82	0·47	0·50
MnO	tr.	0·25	0·13	0·29	0·13
Li_2O	n.d.	—	—	—	—
Cl_2	n.d.	0·04	0·05	—	—
SO_3	n.d.	—	—	—	—
CoO,NiO	n.d.	—	0·06	—	0·03
SrO	n.d.	—	tr.	—	—
Total	100·10	100·99	100·18	100·00	99·97

NORMS AND CLASSIFICATION.

	1.	2.	3.
Orthoclase	12·79	12·23	17·79
Albite	28·82	24·63	34·58
Anorthite	19·74	26·41	18·07
Nepheline	1·42	—	—
Diopside	10·46	7·23	5·94
Hypersthene	—	13·12	4·18
Olivine	11·89	4·32	8·59
Magnetite	3·71	3·94	3·48
Ilmenite	3·65	5·47	4·10
Apatite	1·86	1·68	2·02
Class	2	2	2
Order	5	5	5
Rang	3	3	3
Sub-rang	4	4	4
Magmatic Name	Andose	Andose	Andose

1. Anorthoclase Olivine Basalt, Stony Ck. Falls, Daylesford. Analyst, D. Orr.
2. Anorthoclase Basalt, Sugarloaf Hill, N.N.E. of Woodend. Bull. Geol. Surv. Vic. No. 24, p. 33.
3. Olivine Anorthoclase Trachyte, allot. iv., Parish of Cobaw. Bull. Geol. Surv. Vic. No. 24, p. 25.
4. Average of 161 typical basalts, mostly olivine-bearing. R. A. Daly, Journ. Geol. xvi., p. 409, 1908.
5. Average of 6 basalts, Camperdown district. Mem. Geol. Surv. Vic. No. 9, p. 22, 1910.

In Victoria there are three Kainozoic centres of alkaline volcanic activity, viz.: N.E. Victoria, in the Omeo, St. Bernard Hospice and Mt. Leinster districts; Central Victoria at Macedon; and Western Victoria around Coleraine. Besides the main Macedon area in the central Victoria province, there are two other volcanic foci of alkaline nature recorded by Professor Skeats (1). These are Mount Wilson, about six miles south east of Leonard's Hill, which is composed of trachy-phonolite, and Blue Mountain, four miles north of Blackwood township, which is tentatively described as anorthoclase-olivine-trachyte. In the same paper Professor Skeats describes the Daylesford anorthoclase basalt as an olivine-anorthoclase-trachyte from which it cannot be distinguished either megascopically or microscopically. It is therefore probable that the Blue Mountain occurrence is very similar to the Daylesford type.

The alkaline rocks of the Macedon district (3) include solvsbergites, anorthoclase trachytes, anorthoclase basalts, limburgites, Macedonite, and Woodendite. Analyses of an anorthoclase basalt from Sugarloaf Hill and an olivine anorthoclase trachyte from the Parish of Cobaw are recorded with that of the Daylesford type. The Daylesford rock shows marked chemical affinities with both types. This is reflected in the similar positions which the three rocks occupy in the Quantitative Classification. Though the chemical similarity in the case of the Sugarloaf type and the Daylesford type is very marked, the comparison then ceases. Structurally the Sugarloaf type is of the basalt variety, while the Daylesford type has a well marked characteristic trachytic structure, and might be called an anorthoclase trachy-basalt. Although the Daylesford rock has a distinctly lower SiO_2 content than the olivine anorthoclase trachyte from the Parish of Cobaw, the similarity in the chemical analyses of the two types is very marked, and as both types structurally belong to the trachyte type they are therefore more closely related than the Daylesford type and the Sugarloaf type. The silica content (51·52%) of the latter rock would, according to Hatch's classification, place it in the basalt group with the Daylesford rock.

(*f*) *Origin.*

The origin of the Kainozoic alkaline rocks of Victoria has been discussed by E. W. Skeats and H. S. Summers (3). They consider that at the beginning of the Kainozoic period, Victoria was invaded by a basaltic magma and formed a basic sub-alkaline province. In early Kainozoic times " came the separation and pouring out of the older basalts of the eastern and central portions of Victoria. This left a magma moderately rich in alkalies, and by some process of differentiation alkali magmas separated out into at least three lesser magma basins, viz.: at Omeo, Macedon and Coleraine. On the exhaustion of these lesser magma basins, extrusion once more took place from the main reservoir, giving the newer basalt series." The alkaline lavas of Blue Mountain and Mount Wilson together with the Daylesford anorthoclase basalt may be considered as offshoots from this lesser alkaline magma basin of central Victoria.

In all these other Victorian occurrences of alkaline lavas, whenever evidence of age is obtainable, it points to a slightly earlier period of eruption than the newer basalt. As previously indicated, however, it seems probable that the extrusion of newer basalt types had already commenced in the Daylesford locality when the anorthoclase basalt was extruded. Considering the close intimacy, both in space and time, of the anorthoclase basalt and the newer basalts, it cannot be doubted that both have been derived from a common magma, and are therefore genetically related.

Mineralogically the anorthoclase basalts differ from the normal basalt only in the presence of anorthoclase. This mineral accounts for the higher alkali percentage, and if absent would bring the rock chemically into line with the normal newer basalts, with which it is so intimately associated. Anorthoclase has been recorded in several instances from the newer basalts, and careful microscopical work would no doubt increase the number of occurrences. H. J. Grayson and D. J. Mahony have recorded anorthoclase from the ejected material from Mount Noorat (4), and it is fairly plentiful in the vesicular blocks of scoria at Mount Franklin. Dr. Stillwell has shown it to be present in both the newer and older basalts of Broadmeadows (5). Professor Skeats and Dr. Summers have recorded it in the newer basalt of Ballarat and Macedon (3). These latter two occurrences were as intensely corroded phenocrysts. It is therefore evident that the anorthoclase molecule is present in very minute amounts in the newer basalt magma, and that it separated out at an early stage in the crystallization to be later wholly or partially re-absorbed by the magma.

It is possible that the portion of the magma from which the anorthoclase basalt was derived had been enriched in these anorthoclase crystals. Concentration of the alkalies by resurgent gases has been suggested by R. A. Daly and C. H. Smith. The former (6) regards the source of these gases to be assimilated basic sediment, the most efficient being limestone. The latter (7) regards magmatic or "juvenile" gases to be the more likely effective concentrating agent.

In the rock under discussion, aragonite and zeolites are found in the vesicles, and would indicate the association of magmatic gases with the lava. None of the minerals associated with the more active "mineralisers," however, was detected. In this area the evidence is not sufficient to support one or other of the views as to the source of the magmatic gases. Seepages of carbon dioxide, and the fact that the mineral springs of the district are highly charged with this gas, show that the Ordovician sediments would be competent to supply this gas if assimilated on a sufficiently large scale.

Summary.

Among the newer basalts of the Daylesford district is an alkaline lava which was extruded from Leonard's Hill, six miles south of Daylesford. The area is one of great diversity of surface due to the recent rejuvenation and consequent dissection by the streams. This dissection is discussed, but no conclusive evidence as to its cause could be advanced. A chemical analysis shows that the rock has alkaline affinities. This is borne out by microscopical examination which shows it to be an olivine anorthoclase basalt. The age of the rock is discussed, it being considered to have been extruded subsequently to the commencement of newer basaltic activity. It is compared with normal newer basalt types, and its relation to other Kainozoic alkaline basalts is discussed. It is considered to be genetically related to the newer basalts, and a possible method of concentration of anorthoclase crystals or molecules by resurgent gases, either magmatic or consequent on assimilation, is suggested.

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